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TITLE

Low Pressure, ~~Early Suppression~~

Fast Response Sprinklers

BACKGROUND OF THE INVENTION

Early suppression fast response ("ESFR") sprinklers are a well known and well defined class of ceiling fire sprinklers. ESFR sprinklers were developed in the 1980's by Factory Mutual Research Corporation ("FM") with the assistance of certain sprinkler manufacturers in an effort to provide improved fire protection against certain high-challenge fire hazards. According to FM, ESFR sprinklers combine fast response with greater supplied and actually delivered water densities for greater fire suppression capability. Previous sprinklers (standard sprinklers) provided protection by merely keeping such fires under control. Ultimately the initial fuel source would deplete itself or other fire fighting equipment would have to be brought to the scene to extinguish the fire.

The performance requirements of ESFR sprinklers are set forth in Underwriters Laboratories, Inc. ("UL") STANDARD FOR EARLY-SUPPRESSION FAST-RESPONSE SPRINKLERS UL 1767. This standard was first published in 1990. Factory Mutual Research Corporation ("Factory Mutual" or "FM") also has an Approval Standard For Early Suppression - Fast Response (ESFR) Automatic Sprinklers, Class Number 2008. The current ESFR standards and all earlier ESFR standards of either organization are incorporated by reference herein in their entirety.

Requirements for the installation and use of ESFR sprinklers are included in various standards of the National Fire Protection Association including the Standard for the Installation of Sprinkler Systems, NFPA 13; the Standard for General Storage, NFPA 231; and the Standard for Rack Storage of Materials, NFPA 231c. The current and earlier editions of these standards to the extent that they pertain to ESFR sprinklers are incorporated by reference herein. Installation and use requirements for ESFR sprinklers are also given Loss Prevention Data sheets 2-2, "EARLY SUPPRESSION FAST RESPONSE SPRINKLERS", <u>Factory Mutual System</u>, Factory

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Mutual Engineering Corp., 1987, which is also incorporated by reference herein. Loss Prevention Data sheets 2-8 N, "Installation of Sprinkler Systems", Factory Mutual System, Factory Mutual Engineering Corp., 1989, presents other installation and use requirements for ESFR and other sprinklers generally which are not presented in Loss Prevention Data sheets 2-2 and is also incorporated herein.

The standards specify the construction, performance, installation and operation of ESFR sprinklers with significant particularity. For example, the discharge coefficient (or "K" factor) of an ESFR sprinkler is nominally 14 and must be within the range of 13.5-14.5, where the discharge coefficient is calculated by dividing the flow of water in gallons per minute through the sprinkler by the square root of the pressure of water supplied to the sprinkler in pounds per square inch gauge. Ordinary or standard sprinklers are considered to have response time indices ("RTI") of 100 meter$^{1/2}$second$^{1/2}$ ("m$^{1/2}$sec$^{1/2}$") or more although the response time indices actually reported for these sprinklers have all exceeded 100 m$^{1/2}$sec$^{1/2}$. One special class of faster operating sprinklers exists with response time indices between 50 and 80 m$^{1/2}$sec$^{1/2}$. Existing ESFR sprinklers must exhibit response time indices of less than 40 m$^{1/2}$sec$^{1/2}$. The installation and use standards further require, among other things, that a minimum operating pressure of 50 psi be provided to ESFR sprinklers.

ESFR sprinklers were originally designed to suppress fires in warehouses with thirty-foot ceilings where flammable stock such as certain plastics is piled up to twenty-five feet high in racks. In many instances, available water supplies are not capable of providing a minimum operating pressure of 50 psi to thirty-foot high sprinklers. In such cases, a supplemental pump is needed to boost water pressure before ESFR sprinklers can be used. The cost of providing an auxiliary pump can be significant. For example, in protecting a 40,000 square foot building with ESFR sprinklers, it is estimated that the cost of providing an auxiliary pump can represent about twenty-five (25) per cent of the entire cost of the installed sprinkler system. In certain installations, a second, back-up pump may be needed. If comparable protection might be provided at pressures below the current 50 psig minimum required pressured for ESFR sprinklers, the need for a pump might be avoided. In instances where a pump

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would be required in any event, lower pressure requirements may permit the use of a lower capacity, less expensive pump or the use of the same pump with smaller diameter, higher friction but less expensive supply lines. Each of these three possible options could provide significant savings in installation costs of ESFR sprinklers.

BRIEF SUMMARY OF THE INVENTION

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In one aspect the invention is a low pressure, ~~early suppression~~ fast response sprinkler comprising a generally tubular body having an inlet end, an opposing discharge end and an internal passageway extending between the inlet and discharge ends with a K factor greater than 16 where the K factor equals the flow of water in gallons per minute through the internal passageway divided by the square root of the pressure of water fed into the internal passageway in pounds per square inch gauge; a deflector coupled with the tubular body and spaced from and generally aligned with the discharge end of the internal passageway so as to be impacted by a flow of water issuing from the discharge end of the passageway upon activation of the sprinkler, the deflector being configured and positioned to deflect the flow of water generally radially outwardly all around the sprinkler; a closure releasably positioned at the discharge end of the tubular body so as to close the internal passageway; and a heat responsive trigger mounted to releasably retain the closure at the discharge end of the tubular body, the trigger having a response time indices of less than 100 meter$^{1/2}$ sec$^{1/2}$ (m$^{1/2}$sec$^{1/2}$).

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments of the invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown. In the drawings which are diagrammatic:

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Fig. 1 is an elevation view of an low pressure, early suppression fast response ceiling sprinkler of the present invention;

Fig. 2 is a partial cross-sectional view of the sprinkler taken generally along the lines of 2-2 in Fig. 1;

Fig. 3 is a greatly enlarged view of the encircled area 3 of Fig. 2;

Fig. 4 is a sectional elevation of the trigger;

Fig. 5 is a bottom view of the sprinkler of Fig. 1;

DETAILED DESCRIPTION OF THE INVENTION

In the drawings, like numerals are used to indicate like elements throughout. There is shown in various views in Figs. 1, 2 and 5, a low pressure, early suppression fast response fire sprinkler of the present invention indicated generally at 10. Sprinkler 10 includes a preferably one-piece frame 11 having an at least generally tubular body indicated generally at 12 with a preferably tapered, central, internal passageway 14. The passageway 14 preferably extends straight between an inlet end 15 and a discharge end 16 of the tubular body 12. Threads 17 are provided on the outside of the inlet end 15 to permit the sprinkler 10 to be coupled to a drop or supply pipe (neither depicted) for delivery of water or another fire fighting fluid. The internal passageway 14 of body 12 has a preferably straight central axis A indicated in Figs. 1 and 2.

Sprinkler 10 further includes a closure 20 releasably positioned at the discharge end 16 of the tubular body 12 so as to close the internal passageway 14, a heat responsive trigger indicated generally at 30 mounted to releasably retain the closure 20 at the discharge end 16 of the tubular body 12 closing the passageway 14 until the trigger 30 is activated, and a deflector indicated generally at 60.

Referring to Fig. 1, the frame 11 further includes a pair of support arms 50, 52 which extend generally away from opposite sides of the discharge end 16 of the tubular body 12 and meet to form a tubular knuckle 54 located along central axis A. The arms 50, 52 and knuckle 54 support the deflector 60 positioned juxtaposed to, facing and spaced away from the discharge end 16 of the tubular body 12. While at

least two symmetrically positioned support arms 50, 52 are preferred, three or four support arms might be provided, preferably all symmetrically positioned around and spaced away from the central axis A. Where more than two support arms are provided, they may be separately attached to a tubular body, for example, by being threaded into a flange portion of such separate tubular body.

The frame 11 is preferably enlarged at the discharge end 16 of the tubular body 12 into a circumferential flange 18. The flange 18 is preferably hexagonally shaped with a pair of major opposing parallel flat surfaces or "flats" 18a positioned to receive an open ended wrench or a specially designed hexagonal sprinkler wrench for threading the sprinkler 10 into a drop or other fluid supply line (neither depicted).

Referring to Fig. 2, the internal passageway 14 includes an inwardly tapering portion 14a extending from the inlet end 16 to a cylindrical portion 14b of uniform, reduced diameter. A portion 14c of the passageway immediately downstream from the reduced diameter portion 14b is provided with a greater diameter to receive the closure 20 over the reduced diameter portion 14b. Portion 14c may be outwardly beveled at approximately a 10°-15° angle for its length to foster release of the closure 20 (see Fig. 3). The passageway 14 then abruptly and significantly enlarges in diameter into a cylindrical outlet opening 14d at the discharge end 16 of the frame body 12. A lip 19 is formed around the outlet opening 14d by the provision of a circular groove 14e between the lip 19 and the beveled end of portion 14c of the passageway.

The tubular body 12 may have an axial length of about one and one-third inches with the flange 18 having a length of about one-third inch. The inwardly tapering portion 14a may have a length of about seven-eighths of an inch and taper down at about a one and one-half degree angle to central axis A from a width of 0.98 to a width of 0.93 inches, which is continued for about one-eighth of an inch in reduced diameter portion 14b. Portion 14c may have a minimum diameter of about one inch and a length of about one-sixteenth inch. In the preferred embodiment, the outlet opening 14d may have a diameter of about one and one-third inches and an axial length

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of about one-third inch while the groove 14e has a diameter of about one and one-half inches and an axial length of only about one-eighth inch.

The preferred sprinkler 10 has a nominal discharge coefficient or K factor of 25. The discharge coefficient or K factor equals the flow of water through the internal passageway 14 in gallons per minute divided by the square root of the pressure of water fed into the tubular body in pounds per square inch gauge. The discharge coefficient is governed in a large degree by the smallest cross sectional area of the passageway 14, in other words, the diameter of the cylindrical portion 14b of passageway 14.

The discharge coefficient or "K" factor of a sprinkler is determined by standard flow testing. For ESFR sprinklers, ay 14 is measured first at a pressure of 15 ig, and then in 5 psig increments up to 50 psig and then in 10 psig increments up to 100 psig, and then in 25 psig increments at 125, 150 and 175 psig. The flow is decreased in the same increments back to the original 15 psig value. The flow is measured at each increment of pressure by a flow-measuring device having an accuracy within about 2 percent of the actual flow. The actual flow in gallons per minute is divided by the square root of the pressure of the supplied water in psig at each increment. An average value is then calculated from all of the incremental values and becomes the flow coefficient or "K" factor of the sprinkler.

Discharge coefficients of K factors can be "nominal" values. Typically "nominal" K factors are expressed in standard sizes, which are integer or half integer values. These standard or "nominal" values encompass the stated integer or half integer value plus or minus one-half integer. Thus, a nominal K factor of 25 encompasses all measured K factors between 24.5 and 25.5.

Referring to Fig. 2, the closure 20 preferably is also a subassembly and has an upstream end 20a, which is received over the reduced diameter portion 14b of the passageway 14 in the beveled portion 14c of the passageway. A downstream end 20b of the closure 20 engages a proximal end of the trigger 30. Referring to Fig. 3, the closure 20 is formed by a saddle 22 and a washer subassembly that includes a Belleville washer 26 bearing a sheet of plastic film tape 28, preferably a

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triflouroethylene tape on one side, which is the side of the closure 20 facing the uniform reduced diameter portion 14b of the passageway 14. Saddle 22 is a generally rotationally symmetric body including a cylindrical plug portion 22a, which is received within a center opening of the Belleville washer 26 to stabilize the washer with respect to the saddle 22. The saddle has a circular flange portion 22b with an outer diameter approximately equal to the outer diameter of the Belleville washer 26 and slightly greater than the diameter of reduced diameter portion 14b. Saddle 22 further includes a central circular boss 22c projecting away from the plug portion 22a with a threaded central bore 22d.

The preferred trigger 30 is an assembly which preferably includes a pair of identical, generally L-shaped levers 32. Each lever 32 includes a short arm portion 32a, which is positioned between lip 19 and the downstream end 20b of the closure 20, releasably retaining the closure 20 in the internal passageway 14 closing the passageway. Long arm portions 32b of the levers 32 extend away from discharge end 16 of the tubular body 12 and passageway 14 and are held together by a lever yoke 34. Yoke 34 preferably is a one-piece, generally octagonally-shaped body with a central circular opening. Diametrically opposed portions 34b and 34c of the body are bent around the proximal long ends 32b of the levers 32, thereby holding those ends together and releasably retaining the closure 20 in the passageway 14 so as to close the passageway 14. Cutouts can be provided on the outer edges of the flange portion 22b of the saddle to receive and stabilize the position of the short arm portions 32a of the levers 32.

Referring to Figs. 2 and 4, trigger 30 further includes a retainer body 36, a plunger housing 38 having one end received in the retainer body 36 and a retaining nut received in a remaining end of the plunger housing 38 and forming a plunger chamber 39 receiving a plunger 40. Those and other elements of trigger 30 are best seen in Fig. 4. A retaining nut 43 supports a finned heat collector 44 from a side of the plunger housing 38 opposite the retainer body 36. The finned heat collector 44 is preferably coupled with and thermally insulated from the retaining nut 43 by a thermally insulative support washer 45 of a suitable material such as glass reinforced

nylon. The finned heat collector 44 is hollow and contains a pellet 46 of a metal alloy having a melting temperature at the desired operating or response temperature of the sprinkler 10. Plunger 40 is formed by a pin and a generally bulbous main body 40a along the pin, which divides the pin into upper and lower ends 40b and 40c. The lower pin end 40c of plunger 40 is supported on the metal alloy pellet 46 by a cylindrical bearing disk 47 made of a material such as alumina having significant compressive strength and thermal insulative properties. The upper pin end 40b guides and centers the plunger 40 in the chamber 39. The purpose of the pellet 46, bearing disk 47 and plunger 40 is to support a plurality of balls 48 which extend through bores 38a in the side walls of the plunger housing 38 and into aligned recesses 36a in the retainer body 36 thereby releasably locking the retainer body 36 and plunger housing 38 together. The "free" or "upper end" 36b of the retainer body 36 bears external threads 37 (diagrammatically by phantom), which are received in the threaded central bore 22d of the saddle 22 of the closure 20. Levers 32, which are held together by lever yoke 34, releasably retain closure 20 in the tubular body 12. The retainer body 36 is held through saddle 22 and the remainder of the trigger 30 is coupled with the saddle through the retainer body 36 by means of the balls 48. The balls 48, in turn, are held by the bulbous main body 40a of the plunger 40, which is forced against the balls 48 by tightening of the retaining nut 43 into the plunger housing 38. The alloy pellet 46 will lose its load bearing strength when heated sufficiently allowing the balls to move and permitting the plunger housing 38 and lever yoke 34 to separate from the retainer body 36 and levers 32, respectively, releasing closure 20 with trigger 30 permitting water (or other fire fighting fluid) to pass through the internal passageway 14 and from the discharge end 16 of the passageway 14 and body 12.

The structure and mounting of the deflector 60 are best seen in Figs. 1, 2 and 5. Deflector 60 includes a plate 62, and a nose piece positioned in an opening in the center of the plate 42.

The plate 62 of the deflector is planar and circular with a circular outer perimeter 63 and a plurality of slots 64 extending radially inwardly from the circular perimeter 63 and axially entirely through the plate 62. The plurality of slots 64

surround and define a "slotless" central area 65 as best seen in Fig. 2. As used herein "slotless central area" refers to a circular central area at the center of the deflector, which has a radius equal to the radius of the plate member less the radial length of the longest slot extending radially from the outer perimeter of the plate member in a planar projection of the deflector prependicular to central axis A. Thus, if the nose piece of the deflector overlaps the innermost ends of some or all of the slots, the slotless central area is the planar area of the nose piece which covers the ends of such slots. In the preferred embodiment, the outer diameter of the central area 65 is substantially equivalent to the outer diameter of the frame knuckle 54.

The nose piece 66 has a head portion 66a facing the tubular body 14 which is suggestedly rounded in shape and preferably hemispheric. The head portion 66a supports a shaft portion 66b bearing external threads 67 (indicated diagrammatically by phantom lines) which permit the nose piece 66 to be screwed into the internally threaded knuckle 54. A slot 66c may be provided at the base of the shaft portion 66b to receive a screw driver. The nose piece passes through a circular opening 62a provided in the center of the deflector plate 62 (within the central area 65) and holds the plate 62 firmly to the knuckle 54. The deflector 60 is coupled with the tubular body 14 through knuckle 54 and is positioned juxtaposed to and spaced from the discharge end 16 of the tubular body 12 aligned with the discharge end 16 of the internal passageway central axis A of the tubular body. Nose piece 66 is further preferably provided with a central bore 66d also aligned with the central axis A of the internal passageway 14 and discharge end 16 of the tubular body 12. The deflector 60 is configured by being generally rotationally symmetric and positioned by being centered on central axis A to deflect the flow of water issuing from the discharge end of internal passageway 14 generally symmetrically radially outwardly all around the sprinkler 10. Bore 66d permits water to pass axially entirely through the center of the deflector 60 and down directly under the sprinkler 10. This bore 66d combined with the much larger orifice size of internal passageway 14 in comparison to the diameter of the slotless central area of the deflector has proven sufficient to deliver adequate water densities directly beneath the sprinkler 10 to suppress high challenge fires originating

directly under sprinkler 10 as well as to such fires originating between such sprinklers 10.

Sprinklers 10 of the present invention are installed in accordance with standard ESFR limitations including spacing and height limitations.

For the preferred 25 K factor tubular body having a minimum diameter of 0.930 inches in the reduced diameter cylindrical portion 14b of the internal passageway 14, the head portion 66a of the nose piece 66 is provided with a radius of about one-quarter inch and with a bore 66d having a diameter of about one-eighth inch. The deflector plate 62 is preferably 1.9 inches in outer diameter and about one-tenth of an inch thick. Plate 62 is provided with twelve slots 64 uniformly angularly arrayed in 30° increments around central axis A. Each slot 64 is about one-tenth inch in width and terminates in a radius (semicircle). The diameter of the central area surrounded by and located within the slots 64 is suggestedly about five-eighths inch.

The surface of the knuckle 54 closest to the tubular body 14 is spaced about two and one-half inches from the proximal end of the reduced diameter cylindrical portion 14b of the internal passageway 14. The ratio of the outer diameter of the deflector 60, more particularly the deflector plate 62, to the radial length of the slots 64 is about 3 (1.9/0.635). The plurality of slots 64 provide a total open area of less than one-third but more than one-quarter the total planar area within the circular perimeter 63 of the deflector. All of these values are within the ranges exhibited by existing ESFR sprinklers. However, the ratio of the minimum passageway diameter of the tubular body to the diameter of the central area of the deflector is about 1.5 (0.93 in/0.624 in). The highest ratio previously exhibited in an ESFR sprinkler was less than 1.3.

One of the requirements for an ESFR sprinkler is fast response. Response can be measured in various ways. Factory Mutual and Underwriters Laboratories, use a combination of temperature ratings and response time indices to insure adequately fast response is being provided.

The response time indices or "RTI" is a measure of thermal sensitivity and is related to the thermal inertia of a heat responsive element of a sprinkler. RTI is

insensitive to temperature. For fast-growing industrial fires of the type to be protected by ESFR sprinklers, it is believed that the RTI and temperature rating of the trigger are sufficient to insure adequately fast sprinkler response. The temperature rating is the range of operating temperatures at which the heat responsive element of a sprinkler will activate.

RTI is equal to $\tau u^{1/2}$ where τ is the thermal time constant of the trigger in units of seconds and u is the velocity of the gas across the trigger. RTI is determined experimentally in a wind tunnel by the following equation:

$$RTI = - t_x u^{\frac{1}{2}} / \ln (1 - \Delta T_b / \Delta T_g)$$

where t_x is the actual measured response or actuation time of the sprinkler; u is the gas velocity in the test section with the sprinkler; ΔT_b is the difference between the actuation temperature of the trigger (determined by a separate heat soak test) and the ambient temperature outside the tunnel (i.e. the initial temperature of the sprinkler); and ΔT_b is the difference between the gas temperature within the tunnel where the sprinkler is located and the ambient temperature outside the tunnel. The RTI for ESFR sprinkler is determined with air heated to 197 (±2)°C and passed at a constant velocity of 2.56 (±.03) m/sec over the sprinkler 10 and trigger 30 inserted into the air stream in the pendent position (see Fig. 1) with a plane through frame arms 50, 52 being perpendicular to the direction of the heated air. The aforesaid FM and UL Standards should be consulted for further information if desired.

When fast response was being investigated in the 1980's, the RTI's so-called standard sprinklers were measured and were found to be more than 100 $m^{1/2}sec^{1/2}$ typically up to nearly 400 $m^{1/2}sec^{1/2}$. RTI's of less than 100 $m^{1/2}sec^{1/2}$ are considered faster than standard sprinkler responses. A class of "special" sprinklers has been recognized having RTI's between 80 and 50 $m^{1/2}sec^{1/2}$. RTI values currently acceptable for ESFR sprinklers are less than 40 $m^{1/2}sec^{1/2}$, more particularly 19 to 36 $m^{1/2}sec^{1/2}$.

Applicants' sprinkler is the first known sprinkler to combine any K factor of more than 16 with any trigger (thermally responsive element) having an RTI of less than 100 or even 80 or less $m^{1/2}sec^{1/2}$ for any use and also the first having such combined parameters to successfully suppress a high challenge fire as demonstrated by standard laboratory tests.

The 25 K factor sprinkler 10 will supply 100 gallons per minute at a flow pressure of less than 16 psig while one with a K factor of 26 will supply 100 gallons per minute at just under 15 psi. Applicants believe that 15 psi is the minimum pressure needed to drive drops of the size generated by the sprinkler 10 into the heated plume created by a high challenged fire. The nominal 25 K sprinkler of the present invention therefore is believed to be optimally-sized for its use. However, ESFR sprinklers providing 100 gallon per minute flows at pressures of more than 15 but less than 50 psi can also be commercially valuable. To supply 100 g.p.m. of water at 40 psi requires a K factor of about 16 (15.8). To supply the same amount of water at 30 psig requires a K factor of about 18.5 (18.3) while to supply the same amount of water at 20 psig requires a K factor of about 22.5 (22.4). The reduced diameter portion 14b of the internal passageway might have a diameter greater than .76 inches to yield a K-factor greater than 16, a diameter of about .85 inches to yield a nominal K-factor of about 20, a diameter of about 1.0 inch to yield a K-factor of about 30 and a diamter of about 1.2 inches to yield a K-factor of about 40.

Furthermore, investigations are underway with respect to the suppression of fires even more challenging than those addressed by the original ESFR sprinkler standards. These higher challenges include storage in warehouses piled up to forty feet under forty-five foot ceilings and up to forty-five feet under fifty-foot ceilings. Applicants believe that water might similarly be supplied in even greater quantities at flow pressures of at least 15 psig to successfully suppress such fires. For example, a flow rate of 120 gallons per minute can be supplied at a pressure of 15 psig (or less) by a K factor of about 31, 140 gallons per minute by a K factor of about 36, and 150 gallons per minute by a K factor of less than 40 (38.7). At pressures of 20 psig, 120 gallons per minute can be supplied by a K-factor of about 27 (26.8), 140

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gallons per minute can be supplied by a K-factor of about 31.5 (31.3) and 150 gallons per minute can be supplied by a K-factor of about 33.5.

It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as defined by the appended claims.